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ABSTRACT

The Borough of Havering in London, England undertook a project to devise and implement a computer aided learning program which involved teachers in the production of materials and provided students with a flexible, individualized system of instruction. Materials were developed, and three trials were conducted: (1) a program and equipment test; (2) a test of the effectiveness of the routing algorithm; and (3) a comparison with conventional teaching techniques. This report describes the background of the project, outlines the tests conducted, discusses project management, and summarizes the results of the project's initial years of operation. It concentrates on the organizational and management problems that were encountered, on attempts to assess the success in reaching educational objectives, and on the possible impact of the findings on teaching method and curriculum development. (EMH)

OFF-LINE COMPUTER AIDED LEARNING PROJECT

FINAL REPORT

2

APRIL, 1974.

PREFACE

Upon my earliest excursions into local government, I was instructed by a cynical but respected senior officer of the council to ensure that my reports had the following qualities:-

1) A readable first and last paragraph.

2) Sufficient volume of paper to justify the proposed expenditure.

3) A number of tables and graphs to prove that the matter had been given some thought.

In practice, a more sane reporting policy is required.

It is not my intention, in this Final Report, to produce weighty tomes of evidence of our labours, for this level of documentation already exists and, in accordance with instructions, has been deposited complete with packing cases with both the Social Science Research Council and the Council of the London Borough of Havering. What is more, the research team believes it is right and proper that projects should be documented thoroughly and completely. It has been our policy to document our work continuously and submit reports from time to time to our Advisory Steering Committee rather than leave the documentation of our work to be done in a flurry of activity during the last three or four months of the project. The result of this is that we are now in a position where we have said it all once before. This report, therefore, is more in the nature of a discussion of the project rather than a technical presentation of its results and is concerned with organisational and management problems that we believe we have successfully dealt with as well as attempts to assess the success we have achieved in reaching our initial objectives and to assess the possible impact of our findings on teaching method and curriculum development.

Appendix 1, however, does contain a statement of the complete documentation of the project and brief synopses of the contents of each document.

My final and most pleasurable task in this preface is to record my appreciation of the continuous and unfailing support of the many parties, without whom, this project would have been diminished in stature and quality.

Firstly, to the London Borough of Havering, its Council, Education Committee and Director of Educational Services for an act of faith in embarking upon a journey along untravelled paths and for their continued support and guidance throughout the journey.

Secondly, to the Social Science Research Council and its officers, not only for their funding but also for their continued and active support and their adaptability in taking a system of administration principally orientated towards the Universities and moulding it so that it became responsive to the demands of working with local government.

Thirdly, to our Advisory Steering Committee under the Chairmanship of Prof. Annett of the Open University. This has been a vital sounding board for ideas; an excellent forum for resolving difficulties arising from conflicting interests and a very real help in time of trouble.

Fourthly, to the teachers and heads of schools in Havering where we have not only been allowed to gain practical experience in using our system, but we have been positively encouraged to apply it and have received a tremendous level of support in designing the system.

Fifthly, to an often forgotten body of people, from all walks of life, and to the organisations who originally sponsored the Royal Liberty School Computer Project and thus laid the foundations from which this research project and many other activities have grown.

Finally, I wish to thank the staff of the project, both the past and present for the very real contribution they have made to the design and the quality of implementation of the system. I hesitate in the circumstances to single out any particular person for special mention, but I know all my colleagues will wish me to make an exception in the case of Keith Lovatt, whose strong guidance and sound intellect have done much to mould the final form of the C.A.L. system and the project.

W.R. BRODERICK
APRIL, 1974.

CONTENTS

1.0. INTRODUCTION

There are two characteristics of this project which might have appeared exceptional to the S.S.R.C. when the original grant application was made in 1969.

Firstly, the research was to be conducted in a school and under the auspices of a local education authority. Secondly, the project tended to fall in the category of applied research rather than pure research in education. We were positively encouraged by the fact that the S.S.R.C. recognised that applied research could be no less worthy nor intellectually demanding or stimulating than pure research.

Our reporting policy has been one of continuous reporting throughout the period of the project. The computer system has been documented to the professional standards which are used throughout the centre and is completely described in various levels of detail in the documents listed in Appendix 1. The Educational Material produced as part of this research project, is now in its final proven form and again is detailed in Appendix 1. The three trials we have conducted with the system have each been reported and the results are given completely in three reports on the Development of Educational Material (see again Appendix 1).

This report, for clarity, contains brief descriptions of the computer system and educational material, and the three experiments we have conducted, but it focuses its attention upon the results of this research and the methods and strategies employed to achieve these results.

Some of the original papers which led up to the present project were written as long as six years ago, against a background, where the then National Council for Educational Technology (now the Council for Educational Technology) was pioneering a study of Computer Assisted Learning in its broadest sense, in the face of fairly strong opposition. This opposition had its origins in a very narrow interpretation of Computer Assisted Learning as being on-line and interactive. I think in many professional educationalist's views computer assisted learning was characterised by the turgid quality of the materials presented and the inappropriateness of the

medium to the message. Certainly, the climate has changed but this original background had a fundamental influence on the objectives of the project and the way in which the research team approached their tasks. For instance, this climate influenced us to relegate the computer to a background role and to ensure that it did not interfere and restrict what was likely to be happening in the classroom. We also felt it was essential to ensure that the educational material that was used in the project should be widely acceptable to teachers and produced to the highest possible quality commensurate with the funds available.

Other aspects of the background affected the way the project was formed and developed in its early days. Firstly, I was a practising teacher who had avoided being promoted out of the classroom despite having established the Royal Liberty School Computer Department and with it a pioneering project in computer education. I was sufficiently involved with innovation to be concerned about planning for the future and in 1967 and 1968 I conducted a careful study of the overall role that a computer can play in education at school level. I was still sufficiently unfettered by years of experience in the educational system to hold some irreverent views about how it too could be changed, and, finally, I was convinced of the value of managing educational activities as opposed to letting them happen. The success of this policy was carried forward into this project, much to the surprise of some colleagues at that time, who firmly believed that education should not be managed and research could not be managed. Two ghosts which have now been laid.

2.0. ORIGINAL OBJECTIVES OF THE PROJECT

The original objectives of the project were set out in our application to the Social Science Research Council dated 21st January 1969. These are para-phrased below:-

1) To devise and implement a system for Computer Managed Learning.

2) To structure material for use within this system.

3) To involve teachers in the production of this learning material.

4) To ensure that the Computer Managed Learning system implemented would be capable of being run on the types of computers already available to local authorities for their conventional data processing tasks.

5) To provide a flexible and individualised system of learning.

6) To make the system self improving and incorporate machine intelligence techniques.

7) To investigate the cost effectiveness of the system.

8) To conduct an experiment comparing the effectiveness of this system with that of conventional teaching.

All but one (No. 6) of these objectives have been achieved, although there have been difficulties and set-backs. The implications of these and their effects on the way in which the objectives have been achieved are discussed in this report. However, in order that the discussion can be read within the framework of the system we have devised, it is necessary to describe the system as it now exists. These are outline descriptions and are included here for ease of reference, to understand what we set out to do, and the educational context in which it was set. This is described in the next few sections.

2.1. The System Investigated

The system being investigated relies upon the Computer to select for each individual student a work assignment from an analysis of stored information and of data about the student's abilities and attainments. The student works on this task and returns to the computer a completed questionnaire relating to the task

he has completed. This is analysed by the computer system and the most appropriate next assignment is selected for the student. Information about the student's progress is collected for the benefit of the teacher as also is information about the effectiveness of specific sections of the learning course. The student's work assignments are in fact modules of a completely structured course of instruction.

The use of the computer to control the student's path through a series of programmed tasks allows the logic of the system to be flexible, whereas with conventional teaching machines or programmed learning texts logic has to be defined from the outset and the conventional system is less adaptive therefore to individual circumstances. Further, the more passive systems are less capable (for practical reasons) of continuous updating and modification, whereas any particular learning task in a computer based course can be revised as necessary.

In practice the system works along the following lines:-

1) All students are given an initial booklet defining a structured lesson, including instruction, practical work and diagnostic tests.

2) Students work through this booklet, record on a form their responses to particular questions as soon as they have finished the booklet.

3) At the end of each lesson, these response forms are collected and transmitted to the Computer Centre by a courier.

4) Upon arrival at the Computer Centre the information received from the students is processed and analysed, then, and depending upon an analysis of these responses, the computer system will produce for the student the most suitable selection from its library of possible lessons.

5) This information will be transmitted to the school and the student during his next lesson will proceed with that material. Thus, repeating steps 2, 3 and 4 above.

The Research Team chose to produce teaching material for teaching Respiration and Photosynthesis, as required by most third year school biology courses. The method of teaching chosen is based fundamentally upon the Nuffield approach, however, some significant alterations have been made. In parallel with the production of this teaching material, the team have produced a suite of computer programs to operate the Computer Aided Learning system. The developing system has been tested in a series of three experiments involving more than 700 children and 14 teachers in 15 schools. These ranged from top to bottom of the ability range in both grammar and secondary modern schools.

3.0. THE COMPUTER PROGRAMS

The Computer Programs for this system are written in Hewlett Packard Algol to run on a Hewlett Packard DOS-M Operating System computer in 24K of core. They require a control teletype, a cartridge disc unit, line printer, photo-reader and a paper tape punch.

The programs can be divided into three suites.

a) The Pre-Run Programs

These programs set up files to be used during the course.

b) The Course Programs

These programs perform all the day to day operations on the system.

c) The Post-Course Programs

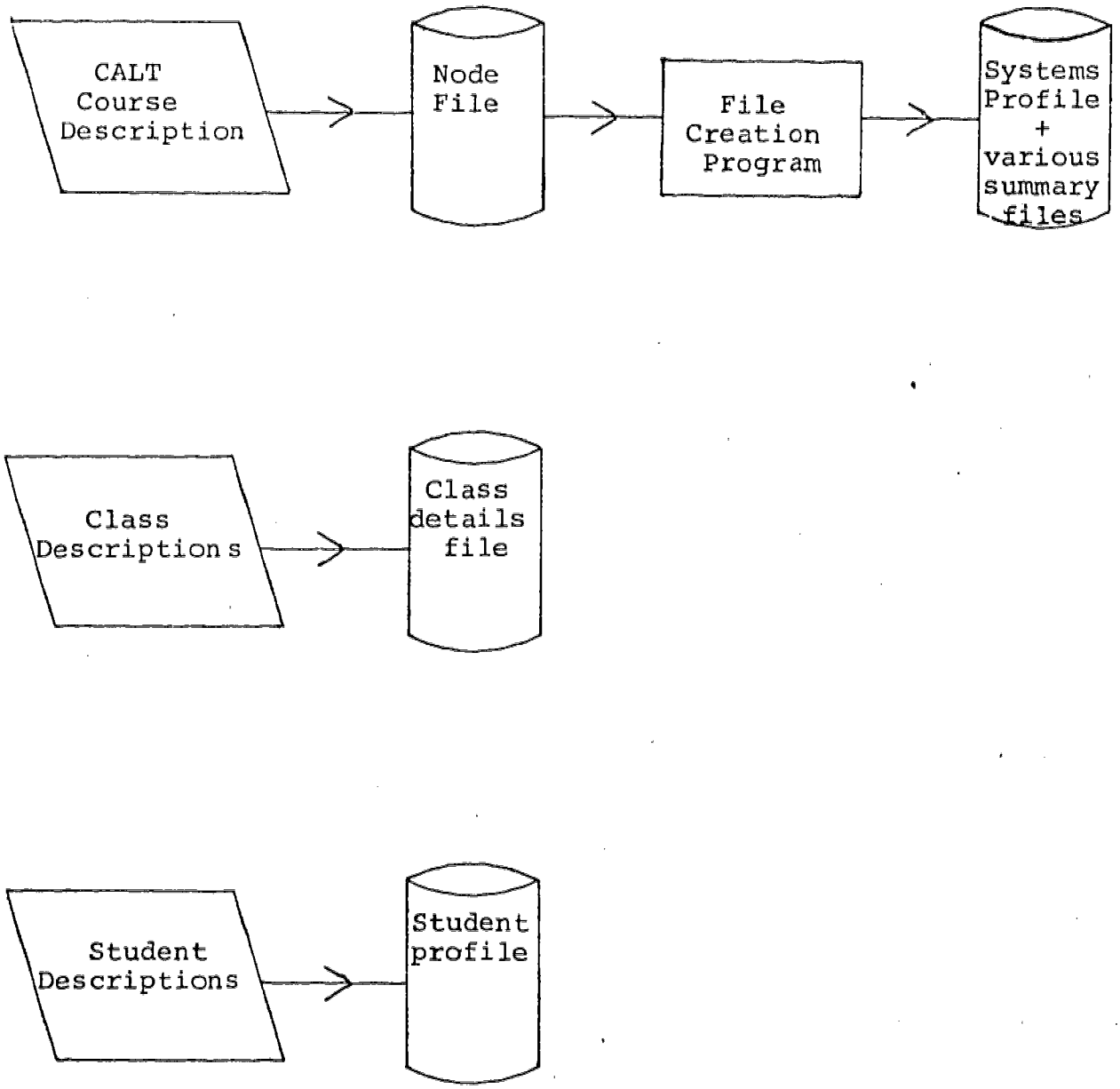
These programs provide final reports, summary and statistical information for research and other purposes.

3.1. Pre-Run Programs

The pre-run programs create four sets of information files. Information describing the Computer Aided Learning Task (CALT) and courses is input via punched paper tape and forms the NODE file. This file is used in turn to form a SYSTEMS PROFILE INDEX and various summary files. The description of the class, supplied by the teacher forms the CLASS DETAILS file. Finally, the students' descriptions form the STUDENT PROFILE. These four files are then used in conjunction with the Course Programs.

The diagram below illustrates this process.

DIAGRAMMATIC REPRESENTATION OF PRE-RUN PROGRAMS



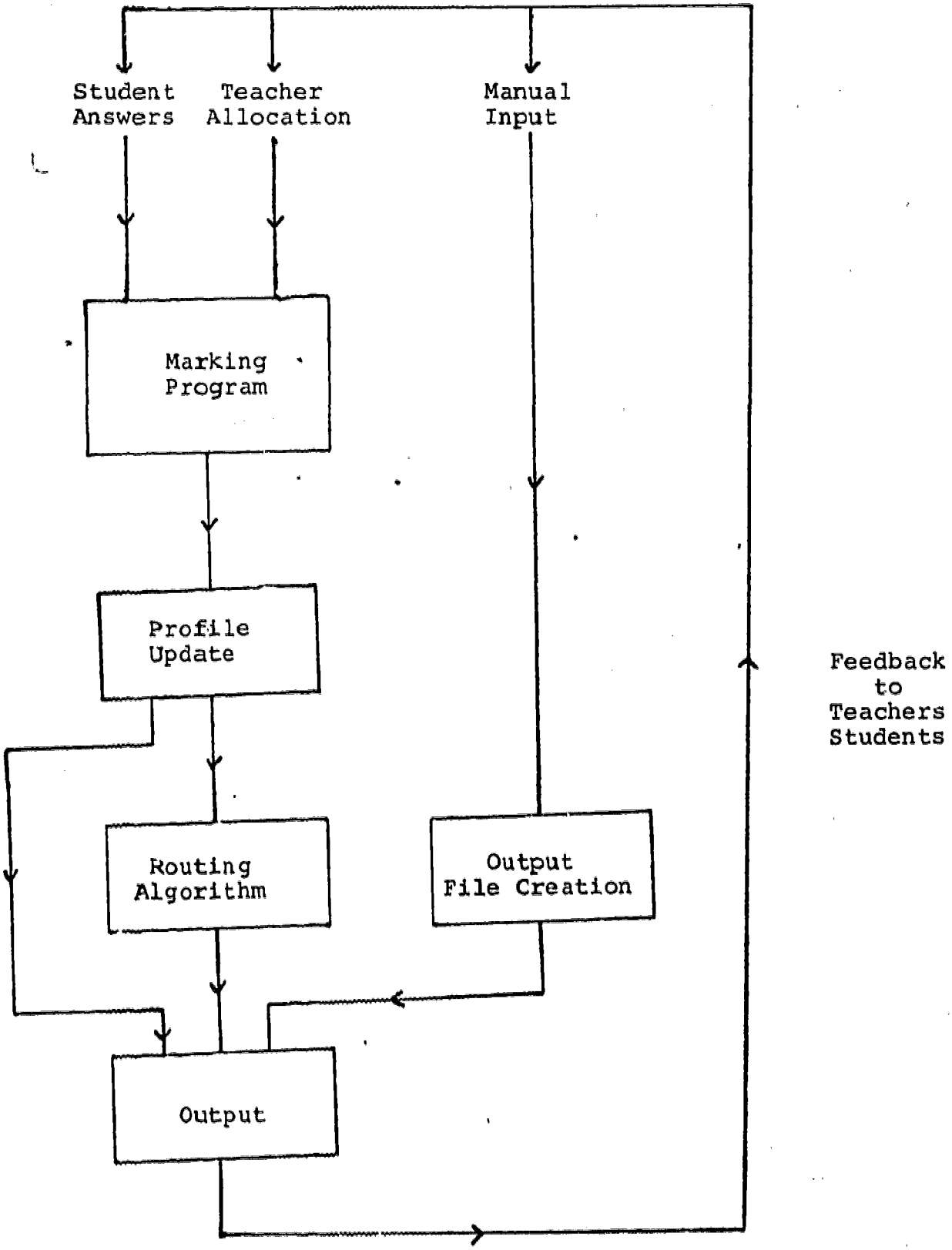
3.2. Course Programs

The Course programs use the files created by the Pre-Run programs plus other information supplied by students and teachers and computer operators, to run the Computer Aided Learning system on a day to day basis.

Student Answer Sheets are received at the Computer Centre, punched into paper tape checked manually and then input to the computer via a RESPONSE INPUT program. Simultaneously, any teacher allocations or modifications are converted into paper tape and are used to form the TEACHER ALLOCATION files. These files are then used as input for the MARKING program. One of the files created by the Marking Program is then used by a program which updates the student and system profiles and it is these files along with the Teacher Allocation files, the Node file and the Class Details file which are used for input to the ROUTING ALGORITHM, which in turn selects the most appropriate next lesson for the student and creates as its output a disc file., This Disc file along with such data as date and class number are used by the output programs. The output programs provide daily and weekly output thus, completing the task of the Course programs.

This process is represented diagrammatically below.

DIAGRAMMATIC REPRESENTATION OF COURSE PROGRAMS

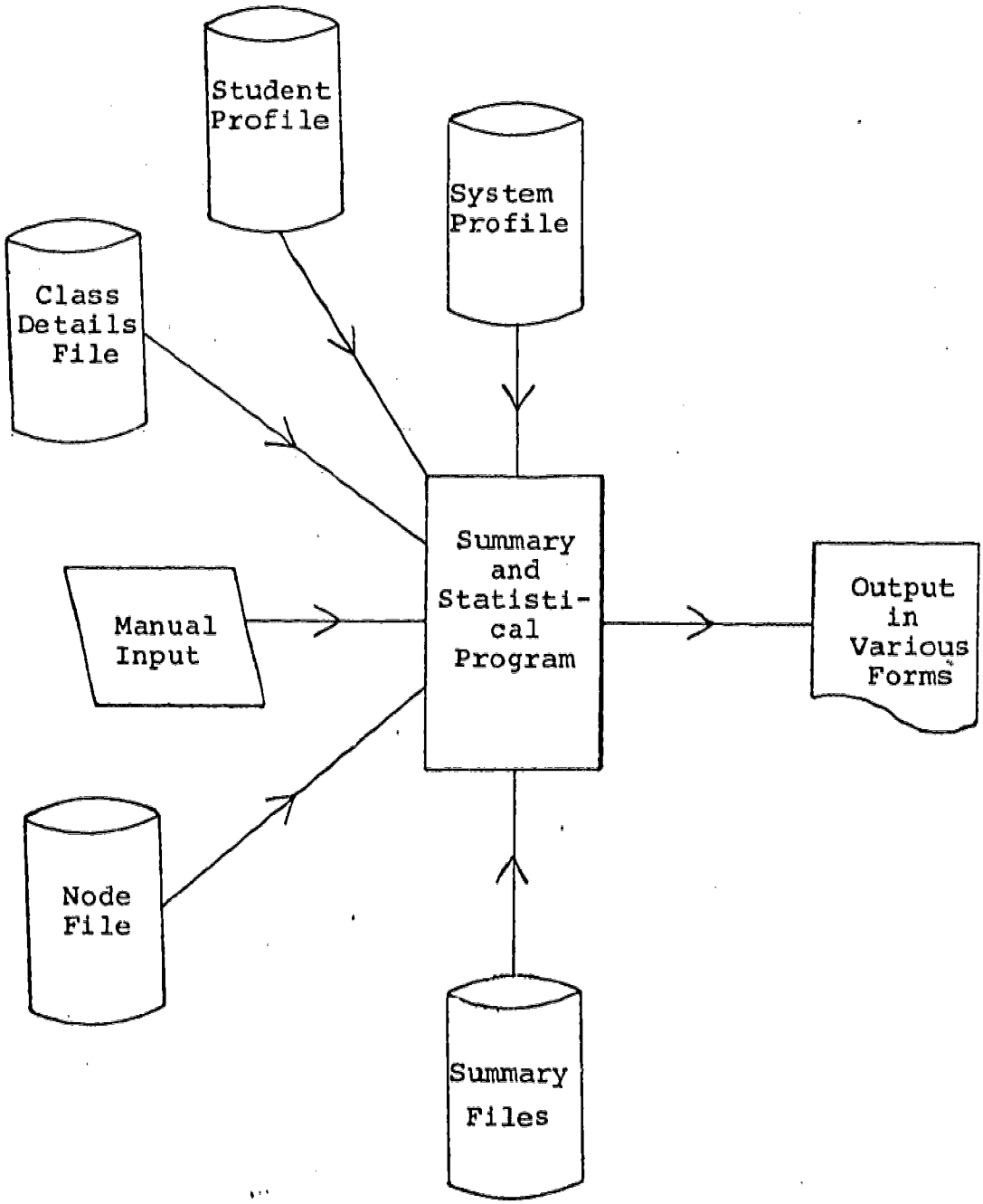


3.3. Post Course Programs

The Post Course Programs, which are used by the research staff, to provide summaries describing the behaviour of the system and statistical information and also the final reports for schools call upon a number of disc files. Data can be taken from them in different combinations for different purposes and they provide a variety of forms of output for later study and analysis.

The diagram below illustrates this activity.

DIAGRAM OF POST COURSE PROGRAMS



4.0. THE OPERATION OF THE SYSTEM

All the students upon entering the sytem are given a pre-course test which is used to create a profile of information about

a) the student's ability and aptitudes,

b) his pre-knowledge of the learning materials and

c) the pre-requisites for following the course.

This test, like all the others in the course, is marked by the computer which simultaneously updates the student's profile. Subsequently, using a "routing algorithm" the computer selects the next lesson for the student. At this stage it prints out

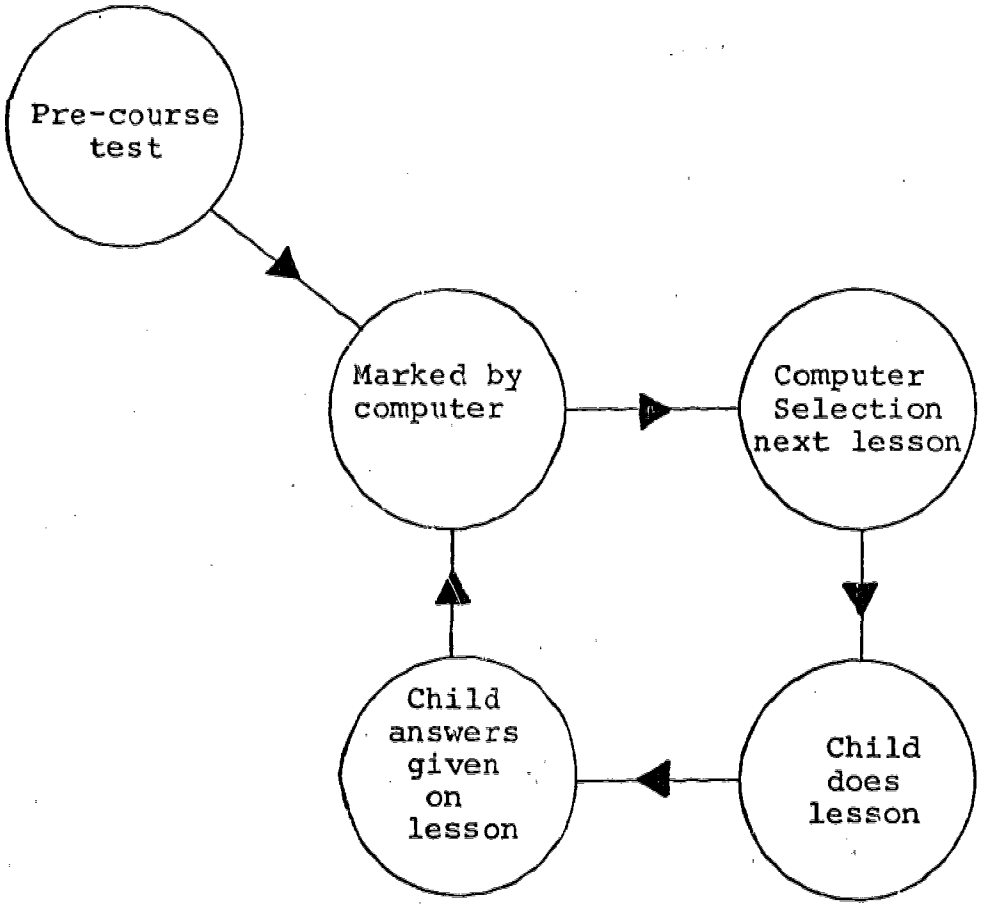
a) for the student, information about what he has to do during his next lesson

b) for the teacher, information about what the whole class is doing and

c) for the laboratory assistant, what apparatus needs to be prepared.

This output from the computer is taken to the child's school by courier, the child does the lesson as directed. At the end of the lesson the student answers (usually in written form) some diagnostic and predictive questions on what he has learnt during the lesson. These answers are collected by the teacher and returned to the Computer Centre by courier. They are then punched into paper tape, marked by the computer and the cycle continued.

This situation can be shown diagrammatically in the figure below.



The role of the teacher in this system is different to that in "conventional" teaching. Much of the instructional role is removed and replaced by the need to help individuals with their specific difficulties. The computer provides the teacher with information to help him manage his classroom and the students learning within it. Before a lesson the teacher is given printed reports on the student's achievement to date in the course, on the work allocated to them for the next lesson and on what the laboratory technician and teacher need to prepare for the next lesson (including equipment and group tutorials respectively).

5.0. WRITING EDUCATIONAL MATERIAL

The first choice which we were faced with was that of the subject area. This had to be an area which was self contained and reasonably structured. Indeed, the policy adopted was to choose the best person available to be the Educational Analyst, then work in the subject area in which that person had had considerable teaching experience. This led us to a choice between Biology and Geology - Biology was the obvious choice, because most children in Havering secondary schools study Biology and, therefore, we would have a potentially large population to use the system.

Having decided on the subject area, contact was established with the teachers, who would be involved (c.f. objective 3 in the original objectives of the project). They were called upon to help us select both subject area within Biology and consequently the age of students with whom we would work. This initial involvement led us naturally to using the teachers to help us in:-

a) Specifying of the objectives of the course.

b) Reviewing the written material produced.

c) Validating the material by testing it in their classes.

d) Assisting in conducting the trials of the system.

5.1. Respiration

It was agreed initially that we would produce material for the whole of the ability range, but it was decided to produce material for the most able students first. We agreed the course objectives with the teachers concerned for a five week course in Respiration for third year students based upon, but not slavishly following, the Nuffield Biology Curriculum. The course objectives were agreed upon. These objectives fell broadly into four groups:-

a) Those common to all student ability levels.

b) Those specifically for most able students.

c) Those specifically for middle ability students.

d) Those for least able students.

The differences between b, c and d reflect both differences in content and approach.

These were ordered in a hierachical manner using a form of Gagne backward analysis. At the same time test questions were produced to test the achievement of these objectives.

The next stage was the production of Computer Aided Learning Tasks (CALTs) which were the teaching materials with which the students would work and which would provide the students with the information they would need to answer the test questions. The first drafts of these materials were assembled into courses and then tested in schools, independently of the computer system. This operation was repeated to produce suitable materials for the middle ability range and the least able students and when the whole course had been prepared, it was implemented on the computer system.

5.2. Photosynthesis

For reasons given later in the report, it was not possible to follow the same procedure for the Photosynthesis material and the opportunity was taken to investigate different ways of producing material for this system. In each case the educational objectives were agreed with teachers as before and test questions defined by an Educational Analyst. A team of six authors, under a Chairman, was then commissioned to write teaching materials for the most able students. This approach resulted in the production of tested and validated material, some of which was of very high quality. Because the team of authors were working independently, the style of the material lacked coherence and it was decided to adopt a different approach in producing material for the middle range of students.

In this case to provide coherence, two teachers in the same school and both experienced in working with students of this calibre, were commissioned to prepare material for this course. Again, they were working with educational objectives which had been agreed with teachers and specified by the Educational Analyst, who had also prepared the test questions. These teachers wrote and validated their material which was adjudged rather more successful than that produced by the larger team.

The educational material for the least able students in Photosynthesis was written at the Computer Centre by the Educational Analyst, at the same time as the teachers in the school were producing the material for the middle range students.

The Photosynthesis course has not yet been incorporated into the computer system because it is most sensible to test this in the summer when there is sunshine, which will enable photosynthesis to take place. It is expected that this work will be undertaken during the summer of 1974.

6.0. THREE EXPERIMENTS

The plans for the project allowed time for us to conduct three experiments with the complete system. Each experiment was designed and timetabled to benefit from the experience gained from the former ones and give us, wherever possible, time to implement any changes that were required.

In total these three experiments have involved more than 700 children and 14 teachers with using this system over a period of eighteen months. These experiments are described and discussed fully in the Second and Third reports of the Development of Educational Material, which are referred to in Appendix 1. Appendices 2 and 3 contain short descriptions of the student samples, experimental design and results of experiments 2 and 3. This has not been done in the case of the first experiment because the objectives of this experiment were mainly operational rather than educational. It must be emphasised at this stage that the descriptions following refer only to the principal objectives of the experiments and that much other valuable information has been collected.

6.1. The First Experiment

The objectives of this experiment were

a) To see that the system worked.

b) To discover what the operational difficulties were, both in the Computer Centre and in the classroom.

c) To overcome these difficulties.

d) To enable us to measure the cost of this system and,

e) To find out whether in practice the Routing Algorithm did individualise learning.

Finally, it was intended to use this material to indicate where remedial CALTs were required and to produce these before the second experiment.

Results of the first experiment

As a result of this experiment, we discovered that the additional operational cost* of

*by additional operational cost we mean that cost of the courier service, computer time and personnel to operate the CAL system. R. & D. costs are excluded from this figure.

running the Computer Aided Learning System was 25p. per student hour and that some modifications were required to our operational procedures at the Computer Centre to simplify the use of the system. There were some incompatibilities between our programs and the operating system which led to an (apparently) random loss of data. Finally, it was decided that the research staff were not needed to provide the courier service and that we could use one of the local authority's couriers for this purpose. This trial did yield educational data which we were able to combine with that from the second experiment to increase our sample sizes. Because no two students followed the same course through the learning material we were able to conclude that the Routing Algorithm did individualise instruction.

6.2. The Second Experiment

The purpose of this experiment was to explore the effectiveness of the Routing Algorithm and to compare this with manual allocation of CALTs on the basis of pretest scores. One of the objectives of this experiment was to investigate whether the facts discovered from the first experiment, namely, that no two students had taken the same route through the material, made any significant difference to the learning (as measured by the post test) of the students involved.

The experiment was set up using the same CALTs as in the first experiment, with the addition of the remedial CALTs. The experiment was blind, in that neither the teacher or the student knew who was being routed by the computer or directed along a pre-selected course of material which was chosen as a result of the performance in the Pre-Test for the course. This experiment was designed to be a severe test for the Routing Algorithm, but one that was more than justifiable as the algorithm involved a significant amount of computing time and was a costly part of the computer system to produce.

Results of the second experiment

Despite the fact that we ran it with a small population, it was considered to be a worthwhile experiment. We were able to conclude from

this experiment that the routing was of significant value to the learning of students in the lower ability ranges, but that these results were only significant at the 5% level. In any course there is a limit on the upper and lower bounds of material provided. It may be argued that able students did not gain signficantly through the routing procedure since they needed the upper limit of the material incorporated in the system. Therefore, the routing procedure could not help them. We also discovered that we were able to use the local authority's courier service for despatch and collection of materials and that the cost of running the system could be reduced to 2lp. per student hour. As a result of this costing it was agreed that some alterations would be made to the computer programs and to the routing algorithm in particular. These alterations were designed to enable the system to function more quickly, and thus more cheaply.

6.3. The Third Experiment

The principal objective of this experiment was to compare the system with conventional teaching and to try to reduce the operational costs still further. There are fundamental difficulties, which are documented elsewhere, about both the form and validity of any comparison with conventional teaching. An experiment was designed because it was recognised that this comparison had to be made despite the impossibility of conducting a really rigorous experiment. It was decided, however, to weight the experiment against the C.A.L. system. The teachers involved in this trial knew the purpose of the trial and were chosen because each was teaching in the same week two different classes of the same age and ability range. It was agreed that the teachers would have complete access to all the C.A.L. materials, and that the group they taught first in the week would be taught using the C.A.L. system, immediately afterwards they would teach their second group conventionally. The teachers knew what the objectives of the course were and recognised that they were not competing against the computer but seeking to discover whether teacher plus computer was more effective than the teacher alone.

Results of the third experiment

The conclusions that we were able to draw from experiment three were that the teacher with the Computer Aided Learning system was more effective than the teacher alone and this result was significant at the 1% level. We were also able to discover that the cost of operating the C.A.L. system could be reduced to 19p. per student hour.

7.0. SOME PROBLEMS ENCOUNTERED

7.1. Variety of Data Format

The first major problem that we encountered was the incredibly wide variety of formats of data that would be needed to input the student and course descriptions. These, if they had been coded separately, would have involved a vast amount of programming time and effort and as this design work was undertaken at the early stage of the project they would have been very susceptible to the need to be changed during the course of the project. In order to preserve flexibility and reduce the total amount of computer storage and programming time involved in the system, it was decided to produce a general purpose system which could be used widely within the C.A.L. system. This system which we called the FILE DESCRIPTION SYSTEM is described in detail in the document referred to in Appendix 1 - 5(b).

7.2. Computer System

Our second area of difficulty was associated with our computer system. The original project proposal was dependent upon the enhancement of an existing computer system with both additional hardware and software. In the event the computer manufacturer failed to supply equipment which would have enabled the objects of the Research Project to be realised and the legal aspects of this situation are currently receiving consideration. This difficulty forced us to apply to the Social Science Research Council for a supplementary grant to enable the duration of the project to be extended and additional computing equipment to be purchased. These events occurred in a hectic five month period in the middle of 1971.

7.3. Algol v Fortran IV

There was pressure on us when changing machines to change from Algol to Fortran IV. This was a change which was resisted at that time because:-

a) All our expertise and experience was in Algol.

b) Algol was a good language for describing algorithms, and that is how we saw our work.

c) The program translation time from one version of Algol to another would probably be less than from one version of Algol to Fortran IV.

d) We were handling complex logical and data structures which were more sympathetic to programming in Algol than in Fortran.

e) Transferring both the work of this research project and the work of the Computer Centre from one machine to another in the period of less than two months (and with no overlap of machines) gave us almost more work than we could handle at that time.

Despite the above justifications, present pressures on us regarding the future use of the system and the increasing interest, not only within the National Development Programme in Computer Assisted Learning, but more widely, in the transportability of Computer Aided Learning, makes us feel a little sad that we were unable to recode in Fortran IV at that time. I do not, however, regard our failure to have done so, even with the benefit of hindsight as a major failure.

7.4. Staff Illness

Our next and entirely unforseeable problem was the serious illness for nine months of the Educational Analyst on the project. Whilst being absent from work, he continued to make a significant impact on the thinking of the project throughout this time and instigated the experiments referred to earlier using different ways of writing educational material. The fact that this illness was turned to advantage, is a real tribute to him and to his ability to work to the highest possible standards under the most trying conditions. Our sorrow at our colleague's illness was tempered by the fact that it occurred at a time when the project team were concerned principally with re-writing the programs for the new computer system and apart from limiting the volume of educational material produced, no other significant effect was made on the project. On balance we feel that this illness was the main reason why less educational material was produced than was originally intended.

The last major difficulty to be discussed here, is that of evaluation. Without any doubt at all, this has been the greatest educational problem that we have tackled and the most difficult one to solve. We have achieved a solution which is acceptable to all the parties concerned (although not necessarily an optimal solution). Appendix 4 outlines those characteristics of the system that makes evaluation especially difficult in our circumstances.

Many of our problems have arisen due to a conflict of interests. We set about the task of evaluation by posing ourselves the question "who requires us to evaluate this system"? To which we answered "the public, our Education Committee and Council, the S.S.R.C., our colleagues and teachers". We then attempted to pose the questions to which these people would want answers. We often asked them directly. Frankly, this was not a very illuminating experience. We came, ultimately to the conclusion that our evaluation had to satisfy the S.S.R.C., in terms of critical analysis, our local authority, in terms of enabling them to make decisions whether to use the system in the future or not and our teachers in terms of whether they would find the system helping them achieve their educational objectives. We thus came to the conclusion that our evaluation must be descriptive, qualitative and quantitative.

We are still restricted in the evaluation we can do by the fact that the research team is small and that our evaluation can only be short term because:-

a) In a project of limited duration the time that can be spent on evaluation is short and the depth to which it can be carried is limited. (a problem which is exacerbated by the fact that the experiments have to be done at the end of a project of this nature).

b) Our populations are relatively small.

c) Any long term evaluation involving a small amount of educational material, and therefore the impact that it is likely to have on children, is unlikely to show effects which will be discernible at long range through the background haze created by all

the other influences on the child.

There are no simple answers to this problem, but steps have been taken to ensure that in our future work we are supported by outside evaluators and consultants to guide us in this side of our work on future projects.

8.0. PROJECT MANAGEMENT

It was our declared intention to demonstrate that we could manage research as well as learning. The fact that we have achieved our objectives within the time scale specified and within the costs specified initially, will be evidence of this.

The first stage in the design of the management system for our project was the establishment of an Advisory Steering Committee, which would oversee the work of the project. This committee which consisted of representatives of the S.S.R.C., the London Borough of Havering, the Research Team and our two Consultants, has had its role described earlier. Because this committee consisted of a group of people who were themselves interested in the achievement of the objectives of the research they played a positive role in the management and development policies of the project.

8.1. Timetable

When the project was originally proposed a timetable for it was drawn up. This set out in three monthly periods what was expected to be achieved during that period. Despite the difficulties listed earlier, that timetable has been adhered to throughout the project. The purpose of the timetable (which was supplied to every job applicant and certainly scared a few away), was to focus attention on achieving a realistic set of objectives in a carefully laid down time scale and for agreed costs. All the staff working on the project recognised the need to adhere to this timetable or the project would fail. Secondly, all the senior staff of the project were responsible and accountable for achieving (or failing to achieve) the objectives in each period. This responsibility focused their attention on the need to achieve their objectives and their personal role in doing so.

8.2. Financial Control

Our organisational management has been considerably helped by financial management. The professional assistance of the Borough Treasurer of the London Borough of Havering, is gratefully acknowledged, who guided us through the initial costing of the project and set up a cost coding system, which enabled

us to analyse expenditure in detail.

The S.S.R.C.'s system for analysis of expenditure was not found to be especially helpful for our own internal expenditure analysis and prediction and to ensure that runaway expenditure did not take place, annual allocations from the grant were made under various cost headings and the rate of expenditure was monitored to ensure that it fell within the limits laid down. Once the system had been established and due to the thorough budgetting that took place initially, it was not demanding upon the Project Director.

8.3. Interfaces between activities

In C.A.L. research much effort has been concerned with producing author languages. We decided not to do this, but to define in the early stages of the project an interface between educational material and the computer system. This was done for four reasons:-

1) To help us manage the project.

2) To bring the research team together and focus their attention on common problems.

3) To ensure that the system was generalised right from the beginning.

4) To ensure that an Educational Analyst could write his instructions for the computer in a language which was familiar to him, and independent of the computer system being used.

We have no doubt at all that this interface, which allowed the two halves of the project to evolve separately (and out of phase at times) played a significant part in our achieving our objectives. Defining the interface between different activities in a research environment at the beginning of the project can help in the achievement of overall objectives. Despite the fact that this is a difficult and time consuming task, it does focus everybody's attention towards the actual problems to be solved.

8.4. Some consequences of management

Some of the results of the careful management of this project have been quite discernible over the five year period since its inception. The attitude of the local authority and its senior officers has changed from one of healthy suspicion to one of support and respect. The teachers involved with using this system have come to know that they can rely both on the system and the research team, and have expressed the opinion that they wish to continue using the system. This is evidenced by the fact that since the second trial we have had more people wishing to use the system than we have been able to accommodate.

8.5. Planning future project

Reference is made later in this report to our view of the future research and development work needed with this system. It was necessary for us to apply to the Social Science Research Council for a research grant to continue our research before the termination of this project. Ideally, in the opinion of the research team, an extensive research programme was the next logical stage, but in view of the large sum of money involved it was decided to apply for support for a two year project and review the situation towards the end of that stage. This application (Ref: HR 2798/1) was made on 27th September 1973 and was successful. However, it has brought home to us the difficult management situation where one seeks to keep together, for an extended period, a research team which embodies a unique set of skills and experience. Because we are obliged to give these staff three months notice we have to have a decision as to whether or not we will be able to continue our work three to four months in advance of the end of a project. Because it takes roughly twelve weeks for the Social Science Research Council to consider a project costing up to £50,000, this means that an application for further research must be submitted six months before the end of the current project. It takes nearly two months to design the project and have it approved by our local authority before making an application to the S.S.R.C. This constrains us to preparing our application for further research some eight months ahead of the end of the current project. This problem is exacerbated if the project is going to cost more than £50,000, when an application has to be submitted to the S.S.R.C. in August, in which case the result is not made available until the following April. Looking ahead

in our own case, this presents a ridiculous situation in that if we wish to continue with our research beyond the next two years we may need to submit an application to the S.S.R.C. after only four months work on the next phase starting in May. I do think that in areas where continuity of research is desirable the development of a more flexible policy in this matter could be to the S.S.R.C.'s advantage.

8.6. Use of artificial intelligence techniques

When the original project proposal was written we anticipated that benefits could arise from making the system "self improving", by including machine intelligence techniques in our programming. Such techniques have not been included in our work to date because we are not yet convinced that there are any that could make a contribution towards refining or improving the effectiveness of the system. In planning and designing the system there were many techniques and characteristics which we considered building in. The criteria that we used were

a) That we had a very high expectation that they would make a significant contribution to the overall effectiveness of the system.

b) That we could predict what difference they would make to the system.

Despite a study of machine intelligence literature and systems we never were in a position where we had a high expectation that it would make a significant contribution to the overall effectiveness of the system, nor did we feel that we could predict what contribution it might make. This area is, therefore, left open as an area of future investigation and we tend towards the opinion that this may be more appropriately conducted in one of the artificial intelligence research groups than in this Centre.

8.7. Copyright

A study has been made during the course of the project by the Borough Secretary's Department of a way in which the laws of patent and copyright protect material produced under the auspices of this project. The thoroughness of this work is a reflection upon the painstaking way in which it was undertaken by the Borough Secretary and its usefulness has been considerable, not only to ourselves and the Advisory Steering Committee,

but also to various groups outside this project who have faced the same problem in a very similar context.

8.8. Commercial Exploitation

During the autumn of 1972, as soon as it had been demonstrated that the Computer Assisted Learning System worked, the research team and the Advisory Steering Committee decided that within the terms of our contract with the Social Science Research Council we ought to consult the National Research Development Corporation about the commercial exploitation of our system. We accordingly approached the N.R.D.C. However, there was a very considerable delay on the part of the N.R.D.C. in responding and when ultimately they did so their attitude proved negative.

As a result of this delay on the part of the N.R.D.C. we are not as far ahead with the exploration of the commercial exploitation of the C.A.L. system as we would have hoped. However, it was discussed at the penultimate meeting of the Advisory Steering Committee and it was agreed that a consortium approach would probably be the most satisfactory. The establishment of such a consortium is now being studied and preliminary contacts are being made with appropriate industrial concerns.

8.9. Relationship with other bodies

The staff of the research project have travelled extensively both in the United Kingdom and in Europe. This time has been well spent both in terms of disseminating information about other projects. The travel within the United Kingdom and abroad has enabled us to study how different forms of Computer Assisted Learning are operated in different educational philosophies. It has given the research team an overview of the problems involved and focused their attention on areas of need and application for computer assisted learning. There is no doubt that the information obtained from these visits has had a real effect on the total concept of the system and the way in which it has been

implemented. It has also done much to focus our attention on different areas of future application of Computer Managed Learning in general.

The research team have produced a number of internal papers on their work, these papers form the Educational Reports listed in Appendix 1.

We have been restricted, however, in how much we have been able to publish externally because of the necessity of keeping aspects of the work confidential, and by our responsibilities to the S.S.R.C. in terms of the commercial exploitation of the results of the research. Thus, only those aspects of the computer system which are non-specific (e.g. File Description System) have been published along with an overview of the system in "Aspects of Educational Technology". A paper on the educational aspects of the research is in preparation and will be published during 1974. Further papers on the system will be submitted to the World Conference on Computer Education in 1975.

9.0. WHAT NEXT?

A computer aided learning system which teaches six weeks Biology to third year students in the London Borough of Havering and does nothing else is unlikely to justify the energy and resources that have gone into its design and implementation. We must, therefore, study areas in which it can be applied to real and identifiable educational problems as well as those which can be studied for research purposes.

9.1. Identification of other subjects

The material for teaching photosynthesis is going to be incorporated in the system this summer and it is expected to become publicly available in the autumn. Plans are in hand for implementing a teacher independent course in the computer language BASIC before the end of this year and consideration is being given to developing Computer Aided VIth form courses in either Modern Languages or Mathematics for the non-specialist. Finally, a Design Study in Computer Assisted Learning has just been completed under the auspices of the National Development Programme, to investigate a curriculum model that can be used with a computer system to provide Remedial Reading for seven year old students.

9.2. Availability of the computer system

At the moment the computer programs will run on Hewlett Packard Disc Operating System computers with appropriate core storage and peripherals. These programs will have to be translated on to IBM, ICL and Honeywell computers if they are to become more widely available to local authorities and universities. Hopefully, other institutions using the system would also produce teaching material for use on it. Thus, we see a long term programme of dissemination as being a possibility. This, however, will only be successful if the system meets real educational needs and can demonstrably make a real contribution to the learning of the students who use it.

9.3. Operational Costs

The present level of operational costs is about 10% or less of the costs of further and higher education. It becomes much more significant, however, when compared with the costs of secondary and primary education.

This is especially true when it is recognised that the cost of running this system is an additional cost over and above that of conventional teaching. Every effort must be made in the future work on the system to both increase its effectiveness and reduce its operational costs. Thus, all development work must assume a responsibility to ensure that it is a realistically viable system for implementation on a wider scale.

9.4. Future research

In our application to the Social Science Research Council for our next research project based on this system, we have outlined the areas of future research which we felt had already been identified. These are listed briefly here and are divided into four main areas.

i) Routing Algorithm

A. Investigation of different automatic routing methods for which the computer is in control (including different algorithms).

B. Investigation of the effectiveness of teacher selected routes on student learning.

C. Investigation of the effects of student selected routes on student learning.

ii) Output Methods

D. Thorough investigation of the form of the output to teachers and students.

E. Investigation of the methods of assessing individual student progress in open ended teaching situations.

iii) Teaching Methods

F. Investigation of the effects of students working in small fixed groups throughout the course.

G. Thorough investigation of the teacher taught lessons with the computer marked tests for diagnostic and prescriptive purposes.

iv) Student Attributes

H. A study of the effect of different students learning styles on the effectiveness of C.A.L.

I. A study of the effect of personality on the choice of the most suitable teaching/learning method.

It is proposed that some of the additional research will be done using the biology teaching material which has already been written as well as developing other material described above. The advantage of using the biology material initially is that we do have a considerable background of experience of using this course thus experiments can proceed without further delay.

Taking all the factors into account it is estimated that this total foreseeable research activity would involve five years work for a relatively small team. The cost of such a research programme would be £106,000 at June 1973 prices.

10.0. A SUMMARY OF THE ACHIEVEMENTS OF THE PROJECT

It is appropriate, having started this report by studying the initial objectives of the project, and having ranged through the whole life span of the project to a study of future developments, to finish on a note which records our actual achievements to date.

1) A system of Computer Managed Learning has been implemented and demonstrated to work on a mini computer.

2) A system of Computer Managed Learning has been devised in such a way that it is independent of

   a) the subject matter being taught.

   b) the taxonomy of educational objectives being used,

   c) and to a considerable extent of the curriculum model being operated.

3) We know what it costs to operate the system.

4) A system of Computer Managed Learning is possible in organisational terms on a secondary school working environment.

5) The system of Computer Managed Learning is acceptable to teachers in the field of science teaching at least.

6) We have established a pattern of working for the production of Computer Aided Learning Tasks, which is both effective and useful with other subjects than Biology.

7) We have established that a group of teachers operating with Computer Managed Learning are more effective than the same group operating without it.

8) We have identified further areas of research which will refine our knowledge about the system.

9) We are convinced that a Computer Managed Learning system can be a powerful test-bed for educational research.

Ultimately, our work and its value must be evaluated by the impact it makes on Computer Assisted Learning research and development both in the immediate future and longer term. We will be happy that our work should be measured against this yardstick.

APPENDIX 1

C.A.L. PROJECT DOCUMENTATION

1) EDUCATIONAL REPORTS

a) "The Development of Educational Material an Interim Report" - May 1971.

This report describes the educational work on the project. Particular attention is paid to methods of selecting educational objectives, the establishment of a taxonomy system. It includes examples of CAL texts.

b) "The Development of Educational Material The Second Report" - May 1973

This report describes two years work after a) above. It covers additional work on the production of teaching material and test construction. It also contains work on the evaluation of the system, the results of Trials 1 and 2, some discussion of these results and an initial description of the costs of the system.

c) "The Development of Educational Material The Third Report - February 1974

This report covers the work done in the third trial of the C.A.L. system and reports on this under the same headings as used in b) above.

2) TEACHING MATERIAL

a) Student CALTs Level 1

Respiration for the most able group of students. All CALTs numbered 1000 - 1999.

b) Student CALTs Level 2

Respiration for the middle range group of students. All CALTs numbered 2000 - 2999.

c) Student CALTs Level 3

Respiration for the lower ability group of students. All CALTs numbered 3000 - 3999.

d) Enrichment CALTs

For varying ability ranges. All CALTs numbered 5000 - 5999.

e) Remedial CALTs

These provide remedial instruction for all ability ranges. All CALTs numbered 6000 - 6999.

f) Tests

The pre-test for the system - also used as the post-test.

g) CAL Diagrams

Students manual of diagrams for use with f) above.

3) SUPPLEMENTARY EDUCATIONAL MATERIAL

a) CAL in the Classroom

A description of teachers of the operational aspects of the CAL system. Describes their role and gives examples of the output produced by the system.

b) Teachers Manual

A manual to help the teacher use the CAL system. Advises on work patterns, procedures for the teacher to override the computer, how to use the subjective assessment and guidance on the teacher directed tutorials which form some CALTs.

c) Laboratory Technicians Manual

A complete set of instructions to enable the Laboratory Technician to be of maximum assistance to the teacher. It also contains a directory of all apparatus used.

d) Tape/Slide Material

Tape or Slide	For use with CALT no	Brief Description
S	1020	This CALT is a tape/slide tutorial on energy cycles.
T	1020	This tape is the commentary for this CALT which is a tape/slide tutorial.
T	4000	Spoken commentary of CALTs for poor readers.
T	4001	
T	4002	
T	4003	
T	4004	
T	4005	
T	4006	
T	4008	
T	4009	
T	4018	

4) RESPIRATION - INTERFACE DOCUMENTATION

This contains a copy of all interface documents prepared to put the Respiration course into the system.

5) INTERFACE AND ROUTING

a) Educational Interface Specification

This manual describes in detail the interface between the computer programs and the teaching material. It refers to the conceptual structure of the material, the types of responses that can be input and the method of expressing educational information in a form suitable of computer input 4) above is an example of this.

b) File Description System - W.R. Broderick & Margaret E. Bryant

This document describes the flexible method of inputting files used by the CAL system.

c) The Routing Algorithm

This document specifies the routing procedure used to allocate the "most suitable" next lesson to students.

6) COMPUTER SYSTEM

a) The Systems Manual

This manual describes in detail the concept of the system, the structure of the suite of programs, the form of the files and the operating instructions.

b) Examples of Data and Output

This manual provides an illustrative set of data for each program in the system to complement the descriptions in the Systems Manual.

c) Program Documentation

For each program at least a brief description, examples of input and output and flowcharts.

d) Program Listing and Source Statement Tapes

These are provided for all programs in the system.

7) ADMINISTRATIVE NOTES

a) Annual Reports

This file contains copies of each of the Annual Reports to the S.S.R.C.

b) Advisory Steering Committee Minutes

This file contains copies of each of the Minutes of the meetings of this Committee.

9) FINAL REPORT

This file is the Final Report on the Project to the S.S.R.C.

AVAILABILITY

ITEMS UNDER HEADINGS 1 AND 9 ARE PUBLICLY AVAILABLE
ITEMS UNDER HEADINGS 2 AND 3 ARE AVAILABLE ONLY TO USERS OF THE C.A.L. SYSTEM.
OTHER ITEMS ARE CONFIDENTIAL.

APPENDIX 2

TRIAL 2 DESCRIPTION

Object

To discover if the routing algorithm of the computer aided learning system is making any contribution to the gain in pre/post test scores of students using the C.A.L. System in Biology.

Student Sample

A sample of six schools were chosen - one grammar school and five secondary modern schools. This gave a sample of 209 students - 33 of which were from grammar school. At the end of the trial the number of students available for statistical treatment was 154 - 30 of which were from the grammar school.

Experimental Design

The students in each school class were divided into two groups according to their score on pretest 7. The two groups were formed by putting into group 1 the first, fourth, fifth, eighth, ninth etc. students rank order. Whilst into the group 2 the second, third, sixth, seventh etc. Neither teachers or students knew that this subdivision had been made.

One group of students was routed automatically by the computer routing algorithm. The second group of students was given one level of teaching material by the computer according to each students score on pretest 7 as follows:-

Score on Pretest 7 equal or over 70%	- Ability Level 1 material
Score on Pretest 7 equal or over 35%	- Ability Level 2 material
Remainder of students	- Ability Level 3 Material

Both experimental and control groups received work each week for five weeks. From the teachers and students position everything appeared to be routed by the computer.

Results

Results comparing the two samples complete showed no statistical difference in post test scores or gains

for the two groups (77 students in each group). However, if the lower ability students are compared (i.e. those with a pretest score below 56% on pretest 7) then the computer routed group do significantly better.

Raw Gain of Students completing pretest and post test 7. Whole sample

	Experimental (Routed)	Control (Non-routed)
MEAN	13.896	13.143
S.D.	10.953	9.608
N =	77	77

Raw gain of students completing pretest and post test 7 who have pretest score of 55% or below.

	Experimental (Routed)	Control (Non-routed)
MEAN	16.314	12.514
S.D.	13.064	11.136
N =	35	35

APPENDIX 3

TRIAL 3 DESCRIPTION

Object

To compare the post test scores and gain scores of students completing the C.A.L. biology course with the scores of students taught a similar course content in the same time period by the same teacher not using the C.A.L. system.

Student Sample

Seven schools were chosen - three grammar schools and four secondary modern schools. The teachers in each school taught two classes in the same year group. One class was to be the C.A.L. class, the other the non-C.A.L. class. Each group contained approximately 220 students.

Experimental Design

Before the course started students from each of the teacher's two classes were matched on the following basis:-

Sex
Teacher
School
Preknowledge of Subject Matter

The teacher taught each class separately for five weeks. After this time both classes were tested for knowledge of subject matter.

Results

The students taught by the teacher using the C.A.L. system did significantly better on the post test and gain scores than the students taught by the same teacher without the C.A.L. system.

		TEST 7			TEST 9			N
		PRE	POST	GAIN	PRE	POST	GAIN	
CAL CLASSES	MEAN	62.209	73.548*	11.339	17.591	35.139*	17.548+	115
	S.D.	16.718	16.566	9.202	10.224	17.245	12.016	
NON-CAL CLASSES	MEAN	61.809	68.791*	7.470	18.313	30.817*	12.670+	115
	S.D.	16.646	17.786	7.972	10.082	15.368	10.863	

* The difference between the CAL and NON-CAL means is significant (5% level)

+ The difference between these gains is highly significant (1% level)

MATCHED PAIRS

APPENDIX 4

IMPLICATIONS OF DYNAMIC REALLOCATION OF OBJECTIVES

The C.A.L. system as implemented can be best thought of as a series of nodes of a hypothetical network. Each node is a CALT plus its prerequisite plus its post test.

Upon entry into the system, and on each occasion when the computer has to allocate the student a lesson, the computer searches the whole of its library (this search may be restricted but is not in general) for the next lesson. The choice of the next lesson is made on the basis of selecting the most complex lesson from the library of lessons which has prerequisites matched within defined limits to the students learning profile. Each lesson however has a different set of objectives. Thus, the system does not seek to ensure the student covers a specific subset of the total objectives of the course which could be predefined upon entry to the network but rather attempts to ensure that each student has a reasonable chance of progressing successfully with the lesson. The general tendency of the system is to allocate students work which is likely to tax their ability: it will err on the side of being too difficult rather than too simple.

A result of our experiments has been to show that instruction is really individualised in that no two students in Trial 1 followed the same course through the learning material. Thus, it can be argued that:-

a) The terminal objectives of the system cannot be predicted for any student upon entry.

b) The terminal objectives for each student may (and probably will) be different.

How then, is a system like this to be evaluated. Clearly evaluation is not just a statistical exercise. In the circumstances in which this project has been conducted it has had to be a more broadly based exercise. As no norms exist in our C.A.L. system criterion reference techniques must be used but there is no single set of criteria for all students.

In the event we have carried out all the standard statistical procedures and supplemented the information we have obtained by using student questionnaires and teacher interviews, wherever these have been appropriate.

Ultimately, evaluation must produce for us a well documented picture of the system we have developed. The creation of this picture is one of our objectives. The picture will be printed with all the tools we can use. We aim to make this as complete as possible.